Supporting Information for ”Coral microatolls of Martinique (French West Indies) record 230 years of relative sea-level changes due to climate and megathrust tectonics”

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Introduction

In this supporting file, we describe and compare the methods used to calculate relative sea-level trends with coral microatolls (Text S1). More details about the reefs we studied are given in Text S2 and the Text S3 is devoted to the relationship between the HLS of coral microatolls and tidal range. The Text S4 presents the full description of the coral stratigraphy of Ecurie 4, Chancel 1, Raisin 2 and Ecurie 10. The Text S5 gives details about our attempt to quantify the tectonic subsidence that would have occurred around 1950.

All supplementary figures are linked to the Texts S1, S2, S3, S4, and S5 or to the main text, and listed by order of citation in the main text.

Text S1: HLS curves and inferred relative sea-level trends

In order to use the coral stratigraphy, revealed by x-ray, for estimating relative sea-level changes, distinction is made between HLS and HLG (for "Highest Level of Growth") [*Zachariasen*, 1998; *Zachariasen et al.*, 1999, 2000; *Meltzner et al.*, 2010]. HLS corresponds to a truncated growth band, meaning that upward growth was impeded, while HLG corresponds to a complete growth band [*Zachariasen et al.*, 2000]. Submergence or emergence rates are deduced from the HLS curve by using different calculation methods proposed by *Zachariasen* [1998]; *Zachariasen et al.* [2000] and *Meltzner et al.* [2010]. The main calculation method of *Zachariasen* [1998]; *Zachariasen et al.* [2000] only uses the HLS points in the linear regression to infer the trend, while the *Meltzner et al.* [2010] method uses the non eroded HLG points immediately prior to die downs. A comparison of both calculation methods has been performed by using tide gauge records (Figure S3). In Figure S3, we have constructed the hypothetical microatoll growth based on three tide gauges, for the two main microatoll-forming coral species (*Siderastrea siderea* and *Diploria strigosa*) found in the Caribbean, growing at 0.5 cm/yr and 1 cm/yr, respectively. For each tide gauge, we have calculated by linear regression the submergence rate of the tidal record, and for each species the submergence rate using only HLS points (Figure S3 a, c, e), or using HLG points before die downs (Figure S3 b, d, f). We conclude that for each tide gauge, the calculated submergence rates are consistent between coral species, between calculation methods and with those inferred from the instrumental record (Figure S3). Only the uncertainties fluctuate as a function of the number of data points used for the linear regression, and is almost systematically lower for the *Diploria strigosa* species which records more die downs owing to its faster growth rate (Figure S3). However, since *Siderastrea siderea* species records less HLS impingements than corals from *Diploria strigosa* species, the inferred signal is more filtered, which means a better correlation coefficient (Figure S3).

Text S2: Reef Morphology of the three sites we studied

The first sampling area, Pointe Ecurie (GPS location: 14.70°N / 60.90°W), has a 1 - 2 m deep lagoon and a buttress zone where depth increases suddenly from less than 1 m at the reef crest, to more than 10 m, 50 m away from the crest (Figure 2 a). At Pointe Ecurie the reef crest is 350 - 400 m from the coast (Figure 2 a).

At Chancel islet, (GPS location: 14.69°N / 60.89°W, precision $\approx$ 0.05 m), the reef flat forms a shallow lagoon with a depth ranging between 0.5 and 1 m. The lagoon is limited offshore by the reef crest, which lies 250 m from the coastline (Figure S4 a). Beyond the reef crest, the depth increases to more than 10 m within about 40 m in the buttress zone (Figure S4 a).

Finally, at Gros Raisin bay (GPS location: 14.74°N / 60.90°W), from the beach, the slope of the lagoon steadily increases until reaching 1 m of depth. The reef crest is 120 m from the beach and isolates the lagoon from the buttress zone, where depth increases toward the open ocean, reaching 10 m within 40 m of the crest (Figure S5 a).

At each site, coral microatolls were found in the lagoon on a sandy substrate, interspersed with muddy patches at Pointe Ecurie and Chancel islet (Figures S4 a, S5 a, S6, S7 and S8).

Text S3: Relationship between the modern HLS and the tidal range

At Pointe Ecurie, we measured 40 cm of tidal range (Figure 3 a), in agreement with the SHOM predictions for the three days (01/30/08 - 02/01/08) we worked at this first site (blue curves in Figure S9 a). Regarding SHOM predictions, highest tides occurred around 9 a.m to 10 a.m. and lowest tides at 4 p.m. to 6 p.m at Pointe Ecurie (blue curves in Figure S9 a).

However, during the whole period of fieldwork in Martinique (01/30/08 - 02/07/08), the SHOM predicts a maximum tidal range of about 65 cm with the lowest tides occurring at night (Figure S9 a). Therefore, neither the lowest tide nor the highest tide was captured during the three days we spent in the Pointe Ecurie area.

The SHOM tide predictions must be taken with caution. Indeed, although they can be precise as 1 cm in amplitude in areas with smooth bathymetry and straight coastlines, larger discrepancies between the model and the observations are expected in more complex areas, where tidal waves can be disrupted and resonance effects can occur. In addition, the SHOM predictive tide model does not take into account the impact of wind and other atmospheric processes upon the tide, which can significantly affect the sea surface height and hence the coral upward growth (pers. comm. G. Jan, SHOM). Despite these uncertainties, the good agreement at Pointe Ecurie between our observations and the predictions at the time of our water level measurements make us confident in using this simplified SHOM tidal model to link our HLS measurements to the complete tide cycle (outside the range of our direct water level measurements).

The SHOM predictions allow us to infer the height difference between the modern HLS and the reference datum of the lowest tide during the whole period of fieldwork (Figure

S9 a). The HLS (-1.34±0.12 m) was about 15 cm below this low tide datum (-1.2 m) in the Pointe Ecurie area (Figure 3 a).

Likewise, at Chancel islet, the HLS (-1.30±0.12 m) was 20 cm deeper than the measured lowest tide (-1.1 m), but only 10 cm below the low tide datum (-1.2 m) according to SHOM predictions (Figure 3 b).

Finally, at Gros Raisins bay, the modern HLS (-2.95±0.10 m) is 35 cm below the lowest tide we measured (-2.6 m) (Figure 3 c). However, according to the SHOM predictions the HLS is only 10-15 cm below the low tide datum (-2.8 m) (Figure 3 c). The height difference between the modern HLS and the predicted lowest tide seems to be consistent for all three sites. Therefore, all coral microatolls we measured were recording the same sea level in January 2008 and they can be used as precise natural tide gauges.

Over the whole of 2008, the SHOM predicts a maximum tidal range of 85 cm at the tide gauge station of Le Robert (Figure S9 b). This is considered as a microtidal regime, which is the preferred tidal regime for the study of relative sea-level changes using coral microatolls [*Woodroffe and McLean*, 1990; *Smithers and Woodroffe*, 2000]. The period when the corals are the most vulnerable occurs in spring, from the beginning of April to June when lowest tides occurred in the daytime between 9 a.m. and 1 p.m. (Figure S9 b). The modern HLS recorded by coral microatolls is about 5 cm below the annual lowest tide for 2008 (Figure S9 b). However, although the HLS has generally been assumed to track the annual lowest tide [*Sieh et al.*, 1999], more recent studies by *Meltzner et al.* [2006] and *Briggs et al.* [2006] and *Meltzner et al.* [2010] have noted that HLS actually tracks the Extreme Lowest Water level (ELW). On Martinique, we do not know the elevation of the ELW, which may be lower than the predicted annual lowest tide, due to sea-level anomalies and other ocean-atmosphere processes that are not modeled by the SHOM.

Text S4: Coral stratigraphy of Ecurie 4, Chancel 1, Raisin 2 and Ecurie 10

Ecurie 4

Ecurie 4 is located about 80 m west of Ecurie 1 (Figure 3 b). It is a *Siderastrea siderea* which measures about 1.5 m wide and 0.6 m high (Figure 4 b). Several new growths have colonized its center (Figure 8 a). Its modern HLS lies at -1.32±0.06 m of altitude with respect to the total station base (Figure 4 b).

Ecurie 4 began to grow in 1879±4 and first hit its HLS in 1886±3 (Figure 8 a). At this stage the coral had a very flattened shape and the growth band thickness decreased toward the surface (Figure 8 a). These observations could indicate that the coral began to grow in a shallow water level.

Like Ecurie 1, Ecurie 4 has recorded a submergence at rate of about 2.0±0.4 mm/yr (or ±0.2, depending on the calculation method we used) (inset in figure 8 b). Upward growth rates between die downs range between 2.7±0.1 mm/yr and 4.6±0.3 mm/yr (Figure 8 b). The coral upward growth has been disrupted by six major centimetric die downs in 1896±3, 1913±3, 1928±2, 1947±2, 1961±2, and 1989±1, with amplitudes of 5.6 cm, 0.6 cm, 2 cm, 2 cm, 1.5 cm, and 3 cm, respectively (Figure 8 a, b).

As for Ecurie 1, the die down frequency decreased in 1961±2 from one die down every 15-20 years to one die down every 30 years. This change is associated with an increase in the coral's upward growth rates (Figure 8 b).

Chancel 1

Chancel 1 is a *Siderastrea siderea*. Its cup shape is well pronounced (Figure 4 d). It is 2 m wide and 0.6 m high (Figure 4 d). Its modern HLS lies at -1.25±0.02 m of altitude compared to the total station base (Figure 4 d), in agreement with the average modern HLS of the area (Figure 3 b).

Chancel 1 recorded a long stage of free growth at a rate of 4.7±0.1 mm/yr from 1805±6 to 1881±4 (Figure 9 a, b). Its first die down occurred in 1881±4 with 1.5 cm of amplitude (Figure 9 a, b). Three other major die downs disrupted the coral growth in 1896±4, 1948±2 and 1989±1 with amplitudes of 5 cm for the two first events and of 2 cm for the last one (Figure 9 a, b). Although erosion partially removed the upper surface of the coral between 1927±3 and 1948±2 (Figure 9 a, b), a fourth event can be identified in 1931±3 (Figure 9 a, b). This event followed a period of slower upward growth between 1912 and 1931 (Figure 9 b), characterized by a significant decrease of the band thickness toward the surface (Figure 9 a).

Chancel 1 recorded submergence rates ranging between 2.0±0.3 mm/yr and 2.3±0.1 mm/yr, depending on the calculation method we used (inset in figure 9 b), consistent with previously described corals.

The slightly eroded and bioturbated plateau of Chancel 1, associated with a much slower upward growth rate between 1927±3 and 1948±2 (Figure 9 a, b) suggests that the coral was growing very close to its HLS during that time. After 1948±2, the coral grew upward more rapidly at a rate of 4.5±0.1 mm/yr for 40 years and developed a columnar morphology (Figure 9 a, b). This likely indicates that the water depth increased significantly after 1948±2.

Raisin 2

Raisin 2 is a *Siderastrea siderea*, located 70 m from Raisin 1 (Figure S5 c). It is 1.6 m wide and 0.6 m high (Figure 4 f). Only some new growing patches of Raisin 2 were living in January 2008 (Figure 10 a). One sample was taken at the base of the coral for U-Th dating (Figure 10 a and table 1). According to the U-Th age, the coral was partially killed in 2003±4, likely because of the regional bleaching event that occurred in 2005 and killed up to 30% of corals in the Caribbean [*Wilkinson et al.*, 2008].

The modern HLS of Raisin 2 lies at -2.98±0.10 m of altitude compared to that of the total station base (Figure 4 f). It is less accurate than the modern HLS defined by other microatolls because it was measured on discontinuous small colonies instead of on one continuous living rim. The coral base, buried in the sand, was broken during the sampling and not x-rayed (Figure S17). The morphology of the latter basal part indicates that it is an overturned ball-shaped colony, on which the main microatoll-shaped colony has grown. The band counting indicates that the overturning occurred around 1883±6, possibly due to a major hurricane which struck Martinique island in 1891 [*Garnier et al.*, 2015] (Table 4).

We constructed the HLS curve by using the southeast radius. According to the growth rate of the *Siderastrea siderea* species and the band counting we performed on the base, without the benefit of an x-ray, the coral began to grow between 1800 and 1820 (Figure 10 a and S17 b). From the x-rayed slice, our record begins in 1883±6 with the first impingement in 1914±6 (Figure 10). No change of the upward growth rate is observed at that time.

Starting from 1956±5, the upward growth rate decreased to about 3 mm/yr (Figure 10 b), which likely means that the upward coral growth toward the surface was more limited by relative sea-level fluctuations than before. Three die downs were recorded by Raisin 2 in 1956±5, 1976±5, and in 1994±5 with amplitudes of 1 cm, 3 cm, and 5 cm, respectively (Figure 10). A small impingement is noted in 1971±5 (Figure 10 a).

From 1989±5 to 1994±5, Raisin 2 recorded a stable HLS followed by an apparent slow HLS decrease until 2003±4 (Figure 10). Thus the 2003±4 HLS is 10 cm below the modern HLS (Figure 10). With the *Siderastrea siderea* species growing 5 mm/yr at most, it is impossible to reconcile the 2003±4 and 2008 HLS. This suggests that the upper surface was truncated and that the signal between 1995±5 and 2003±4 is not reliable. By taking into account the upper altitude of the new growths of Raisin 2 as the current HLS, we calculate a submergence of about 3.0±1.4 mm/yr and 2.7±0.5 mm/yr (depending on the calculation method we used) since 1914±6 (inset in figure 10 b).

Ecurie 10

Ecurie 10 is a *Diploria strigosa*. Its growth rate is higher than the *Siderastrea siderea* corals [up to 1 cm/yr, *Glynn*, 1973; *Weil-Accardo*, 2014]. Ecurie 10 is about 1 m wide and 0.5 m high (Figure 4 c and 11 a). The upper rim of the coral is dead (Figure 4 c) and lies at -1.28±0.04 m of altitude relative to the total station base (Figure 4 c). However, its modern HLS elevation is about 5 cm below this older surface, at -1.33±0.04 m (Figure 4 c and S16 a).

In 2007, Ecurie 10 recorded a die down (Figure 11 a, b) not recorded by Ecurie 1 and Ecurie 4, probably because they were deeper than Ecurie 10 at that time, (owing to their slower growth rate). Ecurie 10 recently affected by a die down in 2007 has just recovered its upward growth in 2008. Since previous die downs were followed by rapid upward growth to the newly established HLS, it is reasonable to expect that the 2007 die down will be equally followed by a similar growth recovery.

Between 1948±2 and 1977±1, Ecurie 10 grew upward at a rate of 10.4±0.5 mm/yr (Figure 11 a, b). Following a first die down with 1.5 cm of amplitude in 1977±1, the microatoll has recorded four other die downs in 1985±1, 1989±1, 1996±1, and 2007, with amplitudes of 3.5 cm, 5 cm, 1 cm, and 5 cm, respectively (Figure 11 a, b).

Since Ecurie 10 has grown on a pre-existing older ball-shaped coral starting in 1948±2 (Figure 11 a and S16 a), it is uncertain whether the 1948±2 growth band should be considered as the first HLS or not. Treating 1948±2 as the first HLS, we calculate a submergence rate of about 6 mm/yr (inset in figure 11 b), which is much larger than that we calculated for previous microatolls. If we assume, however, that the HLS record of Ecurie 10 began in 1977±1, we calculate a submergence rate ranging between 1.5±2.0 mm/yr and 1.8±2.3 mm/yr for the western radius, depending on the calculation method we used and between 1.7±1.9 mm/yr and 3.1±3.2 mm/yr for the eastern radius (inset in figure 11 b). These values are more consistent with submergence recorded by Ecurie 1 and Ecurie 4.

No variation in die down frequency has been observed for the Ecurie 10 record, which is the shortest record we studied. However, Ecurie 10 grew upward by 30 cm, at about 1 cm/yr between 1948±2 and 1977±1 (Figure 11 a, b), greater than what we observed for *Siderastrea siderea* corals Ecurie 1 and Ecurie 4 (20 cm, Figure 5 a, b and 5 cm, Figure 8 a, b respectively) during their periods of unconstrained growth at the beginning of their development. Moreover, Ecurie 1 and Ecurie 4 grew on a deeper substrate (by 20 cm and 10 cm, respectively) than Ecurie 10 (Figure 4 a, b, c), implying that Ecurie 10 began to grow at shallower depth than Ecurie 1 and Ecurie 4. Overall, these observations may suggest that Ecurie 10 began to grow in a setting of strong sea-level increase.

Text S5: Attempt to quantify the tectonic subsidence of 1950

Ecurie 1, Ecurie 4 and Chancel 1 corals grew upward by 15 - 20 cm between 1950 and 1990 (Figure S21). As these corals were at their HLS before 1950, 10 cm of upward growth could be attributed to long-term submergence at 2.4±0.7 mm/yr (deduced from all coral records, Figure 12 b), whereas 5 - 10 cm may be related to a sudden subsidence (Figure S21). By considering each HLS curve of the three corals, we calculate lower values of subsidence (12.5 cm, 3 - 4 cm and 11 cm, for Ecurie 1 SE, Ecurie 4 and Chancel 1, respectively, Figure S21). The uninterrupted 25 cm of upward growth between 1947±2 and 1989±1 recorded by Raisin 1 could be accounted for by 15 cm of sudden subsidence (Figure S20). Likewise, for Ecurie 10 and Raisin 2, we calculate that 20 cm and 10 cm could be caused by tectonic subsidence (Figure S20). For Ecurie 10, Raisin 1 and Raisin

2, we can not used their respective HLS curve to calculate more precisely the subsidence and the previous subsidence values estimated with their morphology and the long-term submergence of 2.4±0.7 mm/yr are probably overestimated.

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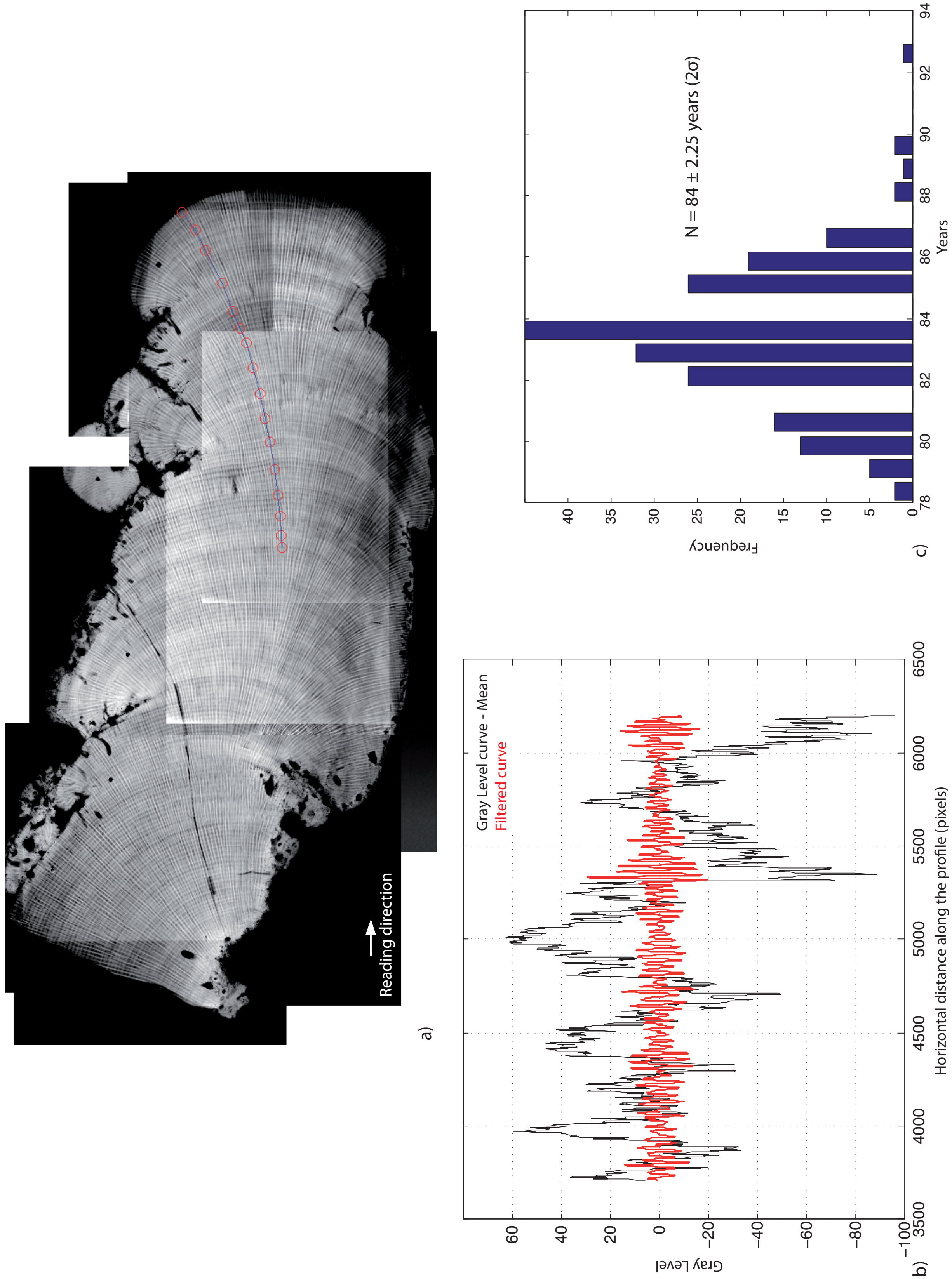

Reading direction
a)
Gray Level curve - Mean
Filtered curve
Gray Level
Horizontal distance along the profile (pixels)
b)
N = 84 ± 2.25 years (2σ)
Frequency
Years
c)

Figure S1. Description of the computing method. a) Manual selection of the profile on the x-ray. b) Calculation of the gray level curve along the profile (black curve) and of the passband-filter to isolate the annual cyclic signal (red curve). c) Calculation of the statistical repartition of the counted bands for 200 random profiles shifted by $\pm$ 20 pixels from the initial profile. N: median value of the gaussian repartition.

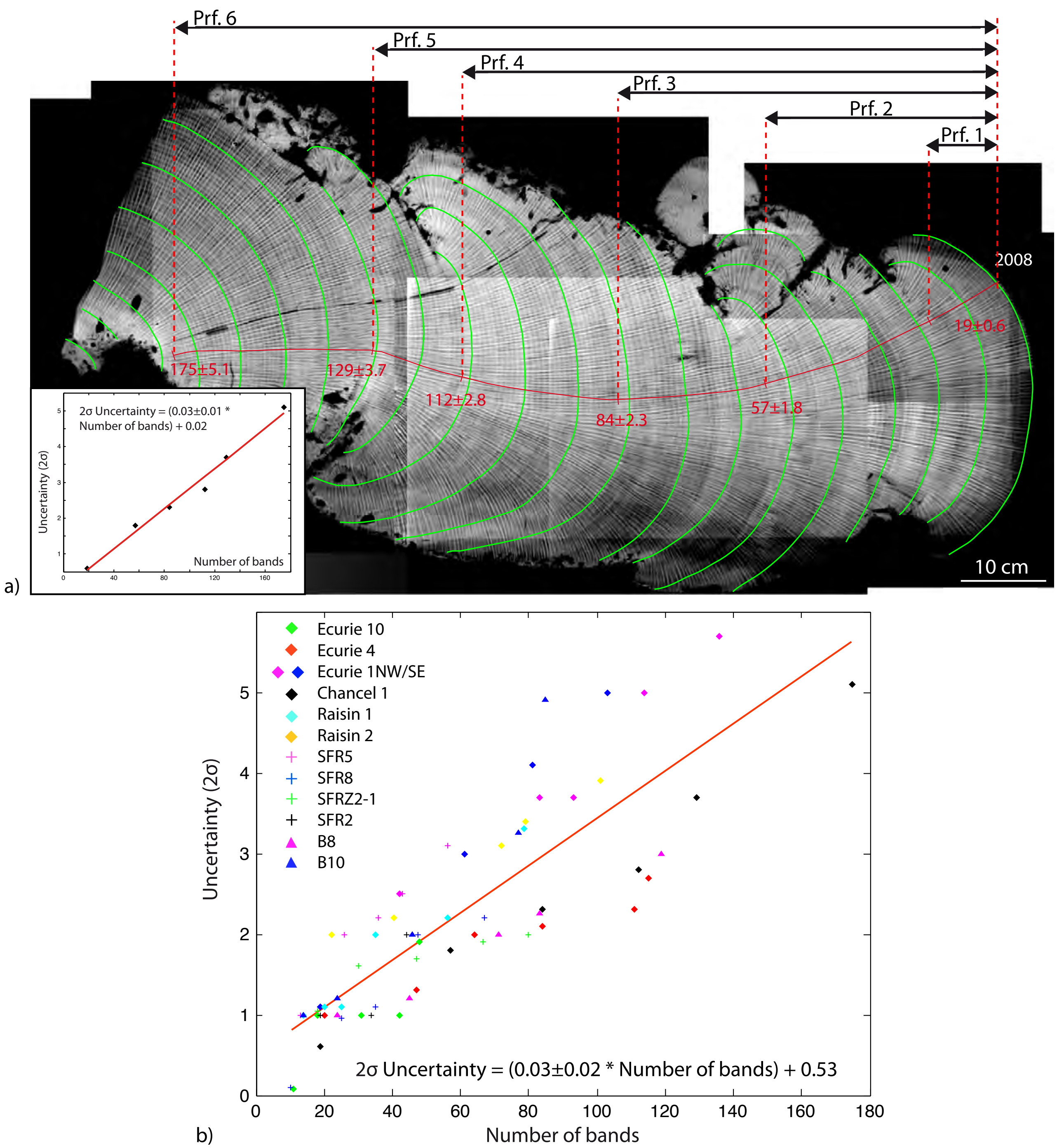

Prf. 6
Prf. 5
Prf. 4
Prf. 3
Prf. 2
Prf. 1
2008
19±0.6
175±5.1
129±3.7
112±2.8
84±2.3
57±1.8
10 cm
2σ Uncertainty = (0.03±0.01 * Number of bands) + 0.02
Uncertainty (2σ)
Number of bands
a)
Ecurie 10
Ecurie 4
Ecurie 1NW/SE
Chancel 1
Raisin 1
Raisin 2
SFR5
SFR8
SFRZ2-1
SFR2
B8
B10
2σ Uncertainty = (0.03±0.02 * Number of bands) + 0.53
Uncertainty (2σ)
Number of bands
b)

Figure S2. a) Example of computing method applied on a high quality x-ray. Green lines: annual growth bands drawn every ten years since the younger growth band of January - February 2008. Red lines: overlapping small profiles (Prf1, Prf2, ..., Prf6). Red numbers: number of counted bands with corresponding 2σ uncertainty for each profile. Inset: Plot of the 2σ uncertainty in function of the number of counted bands. Red line: linear regression with corresponding equation. b) Plot for all x-rays of the 2σ uncertainty in function of the number of counted bands. Red line: linear regression with corresponding equation. Symbols and colors: different x-rays.

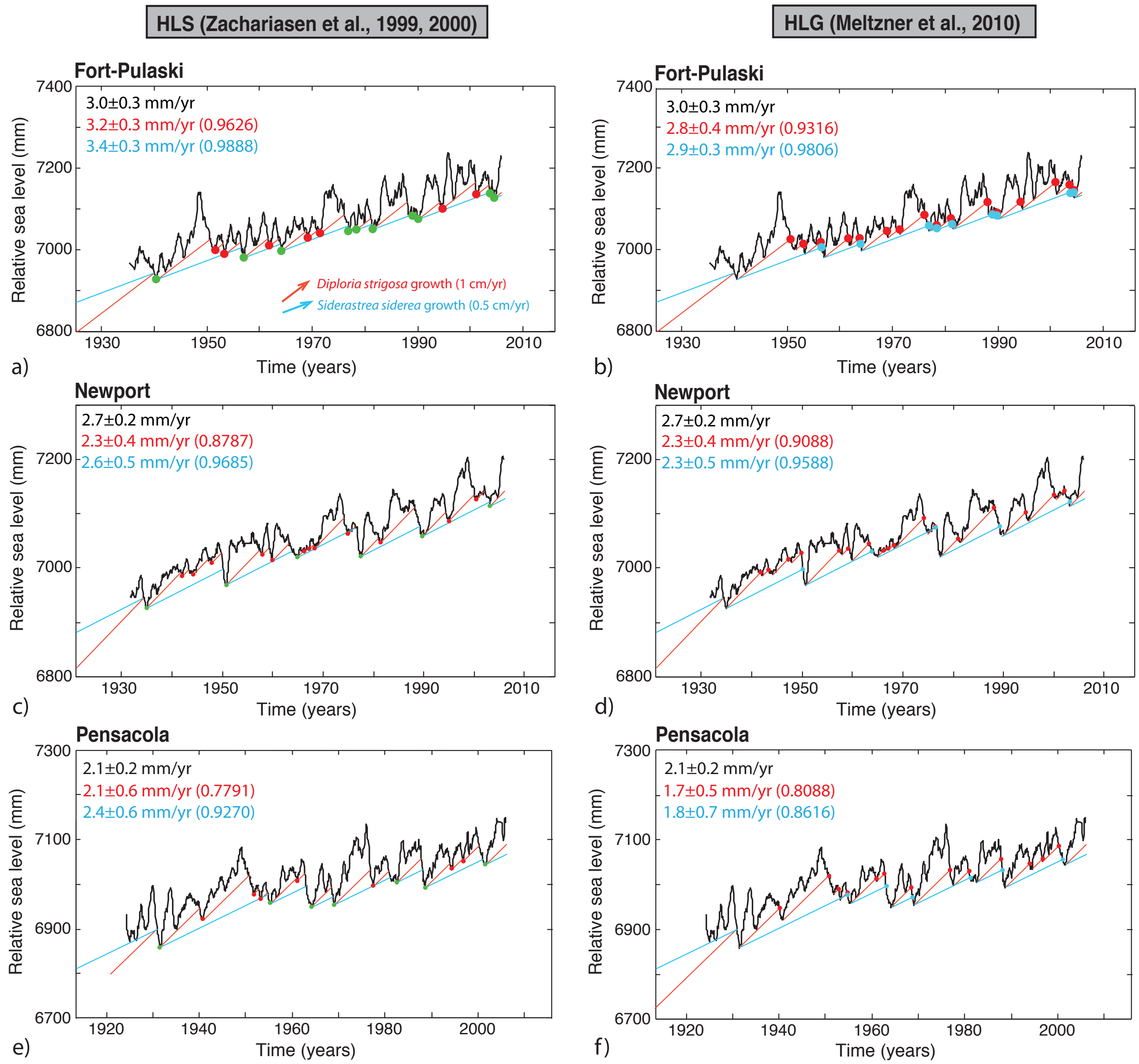

HLS (Zachariasen et al., 1999, 2000)
HLG (Meltzner et al., 2010)
Fort-Pulaski
3.0±0.3 mm/yr
3.2±0.3 mm/yr (0.9626)
3.4±0.3 mm/yr (0.9888)
Diploria strigosa growth (1 cm/yr)
Siderastrea siderea growth (0.5 cm/yr)
a)
Fort-Pulaski
3.0±0.3 mm/yr
2.8±0.4 mm/yr (0.9316)
2.9±0.3 mm/yr (0.9806)
b)
Newport
2.7±0.2 mm/yr
2.3±0.4 mm/yr (0.8787)
2.6±0.5 mm/yr (0.9685)
c)
Newport
2.7±0.2 mm/yr
2.3±0.4 mm/yr (0.9088)
2.3±0.5 mm/yr (0.9588)
d)
Pensacola
2.1±0.2 mm/yr
2.1±0.6 mm/yr (0.7791)
2.4±0.6 mm/yr (0.9270)
e)
Pensacola
2.1±0.2 mm/yr
1.7±0.5 mm/yr (0.8088)
1.8±0.7 mm/yr (0.8616)
f)
Relative sea level (mm)
Time (years)

Figure S3. Hypothetical coral growth based on different tide gauge records. a) and b) Tide gauge of Fort-Pulaski, Georgia. c) and d) Tide gauge of Newport, Rhode Island. e) and f) Tide gauge of Pensacola, Florida. For each tide gauge, data are annual sea level. Submergence rates are calculated by linear regression (number in black). The hypothetical HLS curve for *Diploria strigosa* species (growing at about 1cm/yr) and for *Siderastrea siderea* species (growing at about 0.5 cm/yr) were drawn in function of the tidal record, in red and blue, respectively. For each hypothetical HLS curve, we calculate submergence rate by linear regression with the main method of *Zachariasen et al.* [1999, 2000] (a, c and e) and the one of *Meltzner et al.* [2010] (b, d and f). Numbers in red: rates for *Diploria strigosa* species. Numbers in blue: rates for *Siderastrea siderea* species. Red dots: hypothetical HLS and HLG for *Diploria strigosa* species. Blue dots: hypothetical HLS and HLG for *Siderastrea siderea* species. Green dots: hypothetical HLS and HLG for both species. Correlation coefficients are given between brackets for each linear regression.

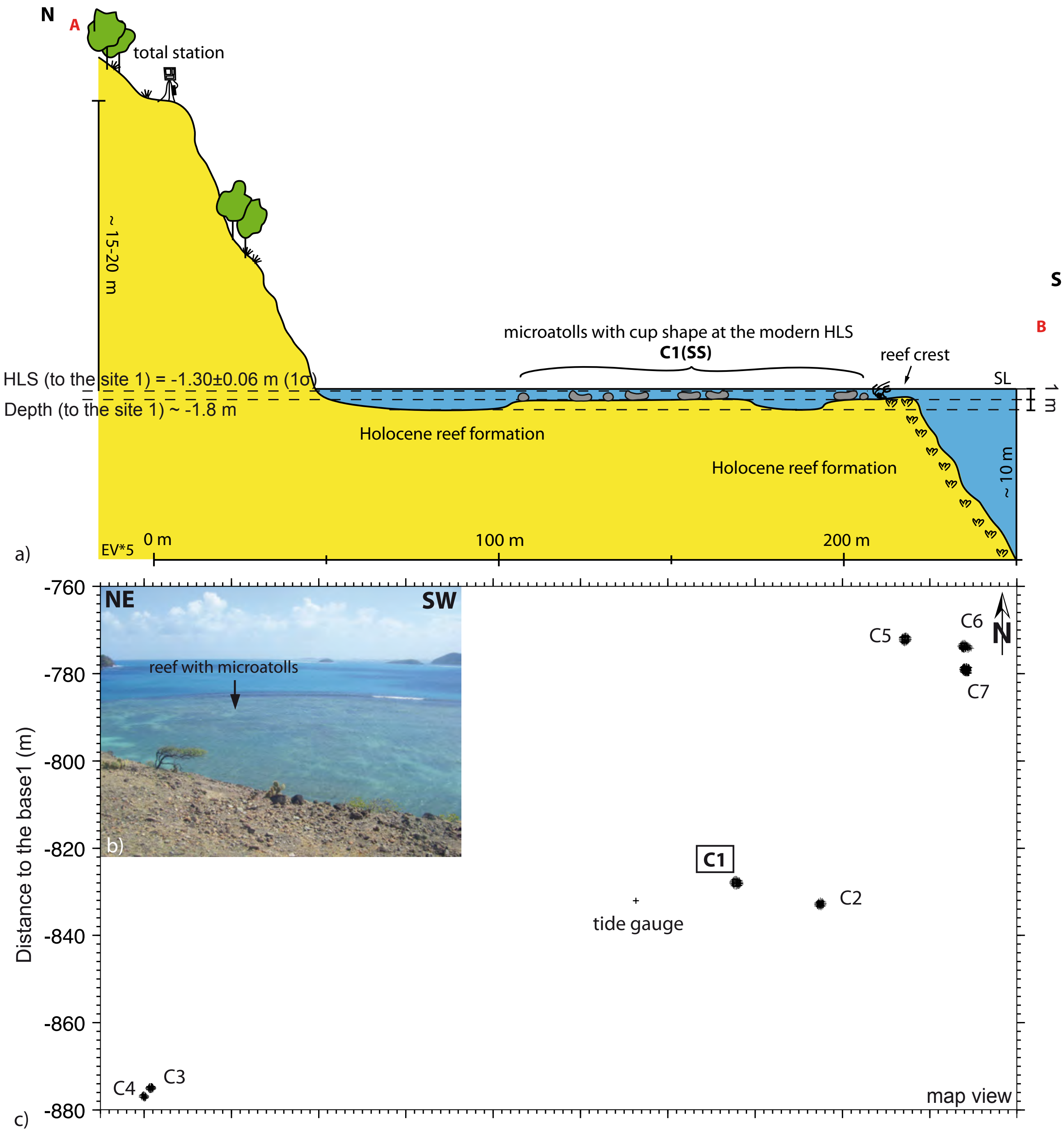


Figure S4. Chancel islet site. a) Bathymetric and topographic (data as in Figure 1 c) profile of the site, from the north coast to the fringing reef south (location in figure 1 c). b) Photography of the site we mapped from the total station base. c) Map view of the total station survey. Black crosses: corals mapped. C1 was sampled (black box). Only corals from *Siderastrea siderea* species were found in this area.

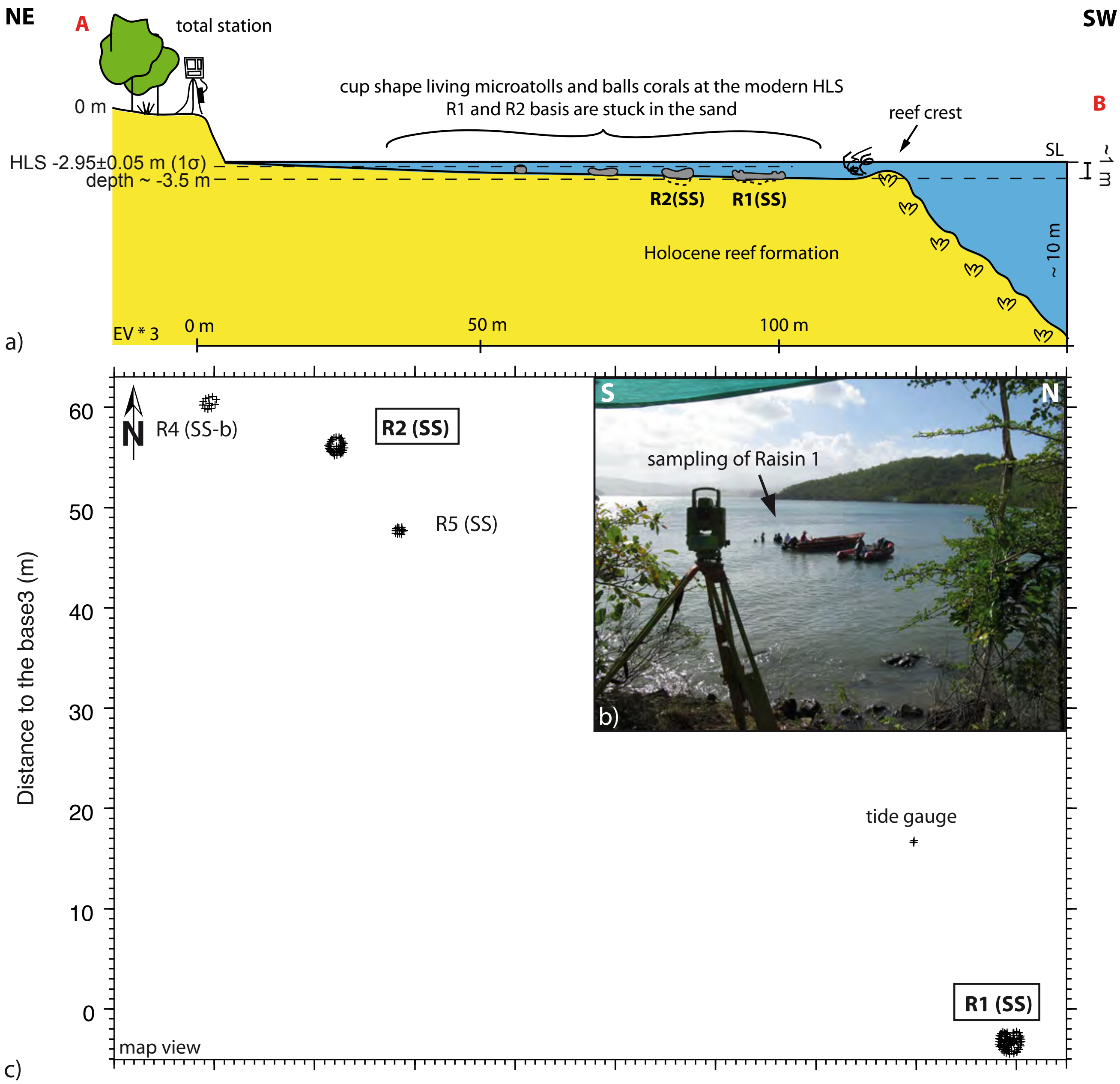


Figure S5. Gros Raisins Bay site. a) Bathymetric and topographic (data as in Figure 1 c) profile of the site, from the northeast coast to the fringing reef southwest (location in figure 1 c). b) Photography of the site we mapped from the total station base. c) Map view of the total station surveyed points (black crosses). R1 and R2 were sampled (black boxes). Only corals from *Siderastrea siderea* species were found in the area. SS-b: SS with hemispherical growth.

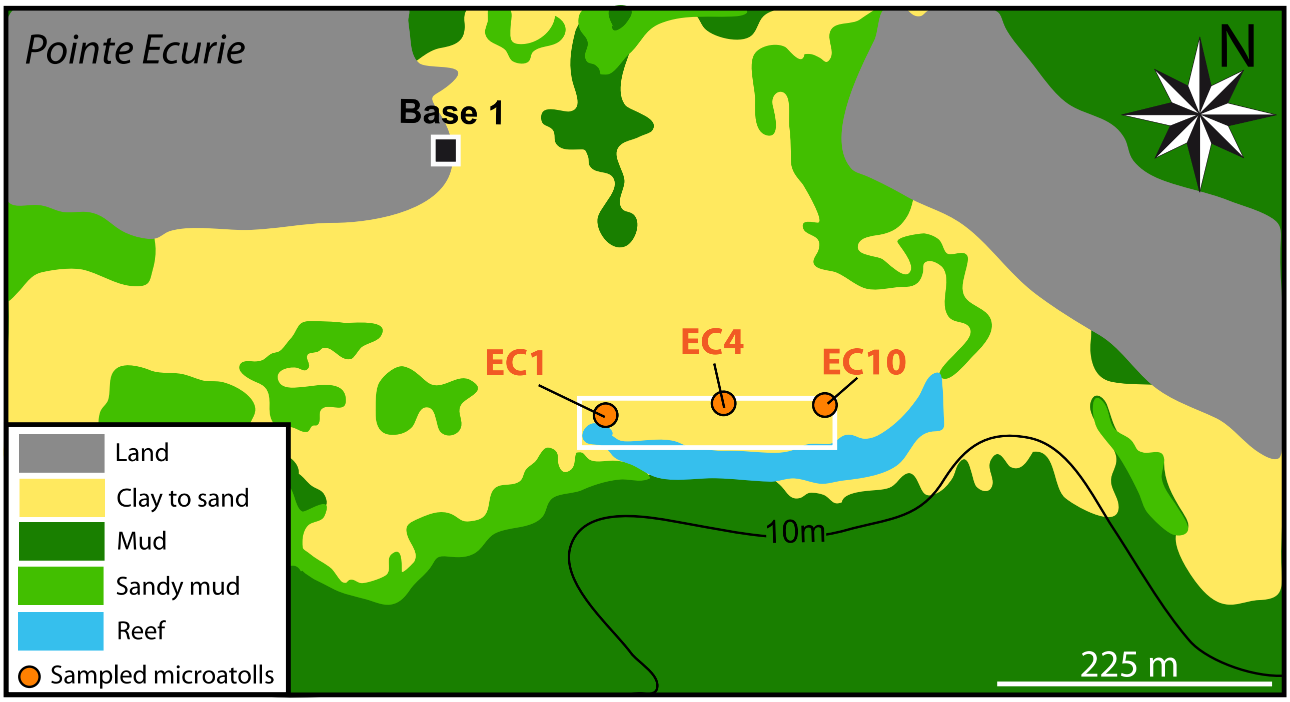


Figure S6. Environmental setting of the sampling area at Pointe Ecurie, based on the superficial geological map of the insular plateau of the Martinique (scale of 1/25000) [*Augris et al.*, 2000].

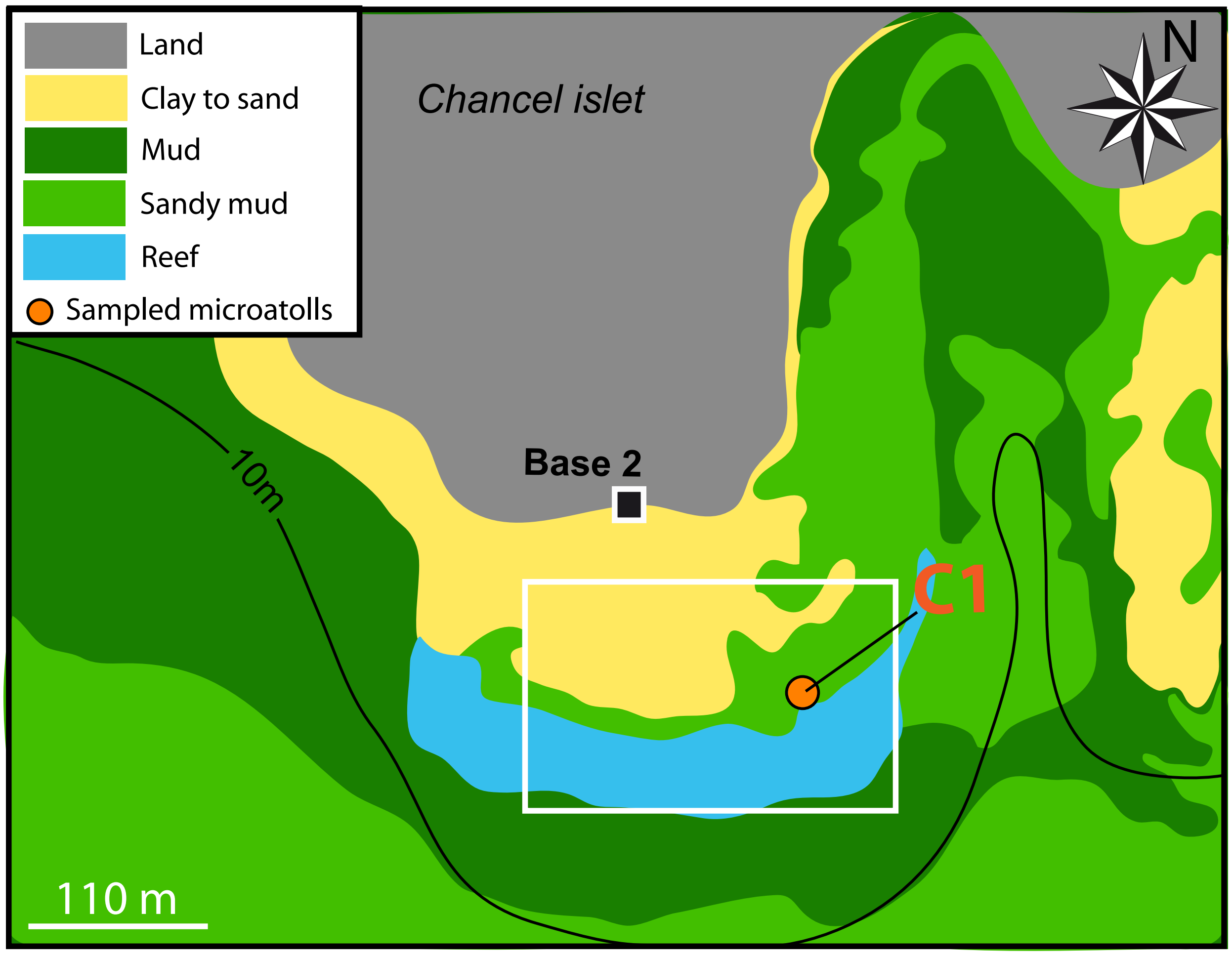


Figure S7. Environmental setting of the sampling area at Chancel islet, based on the superficial geological map of the insular plateau of the Martinique (scale of 1/25000) [*Augris et al.*, 2000].

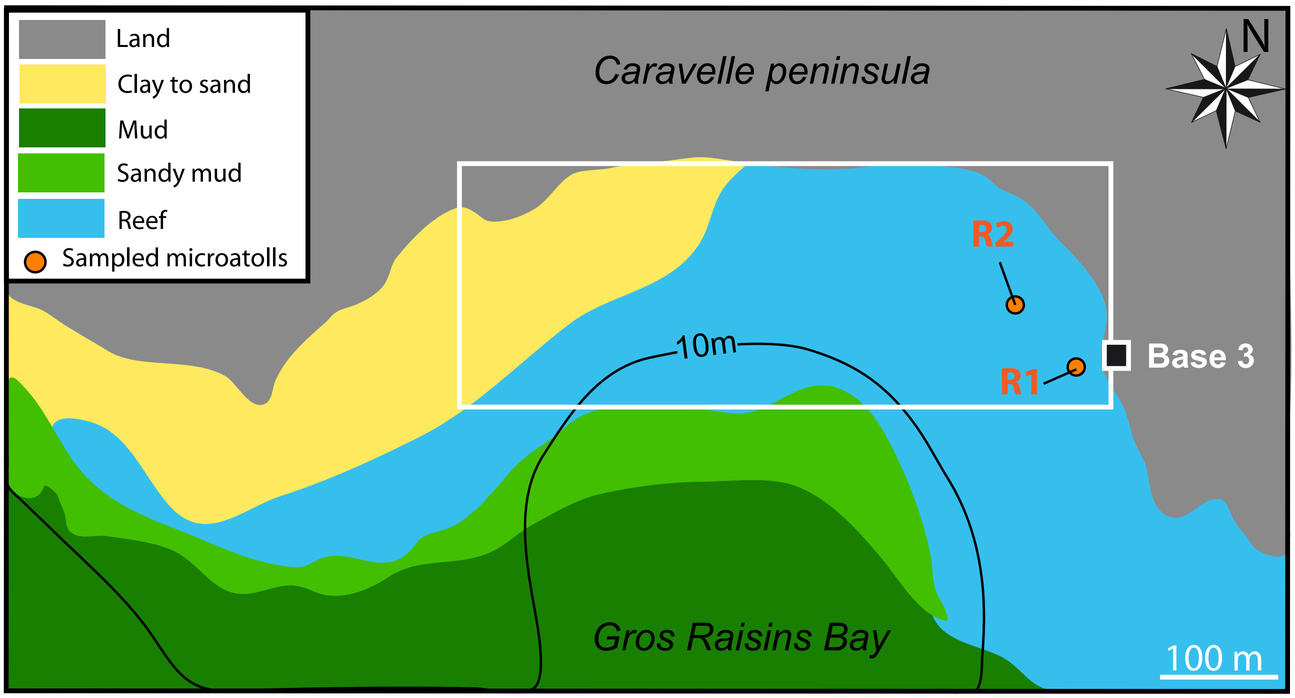


Figure S8. Environmental setting of the sampling area at Gros Raisin bay, based on the superficial geological map of the insular plateau of the Martinique (scale of 1/25000) [*Augris et al.*, 2000].

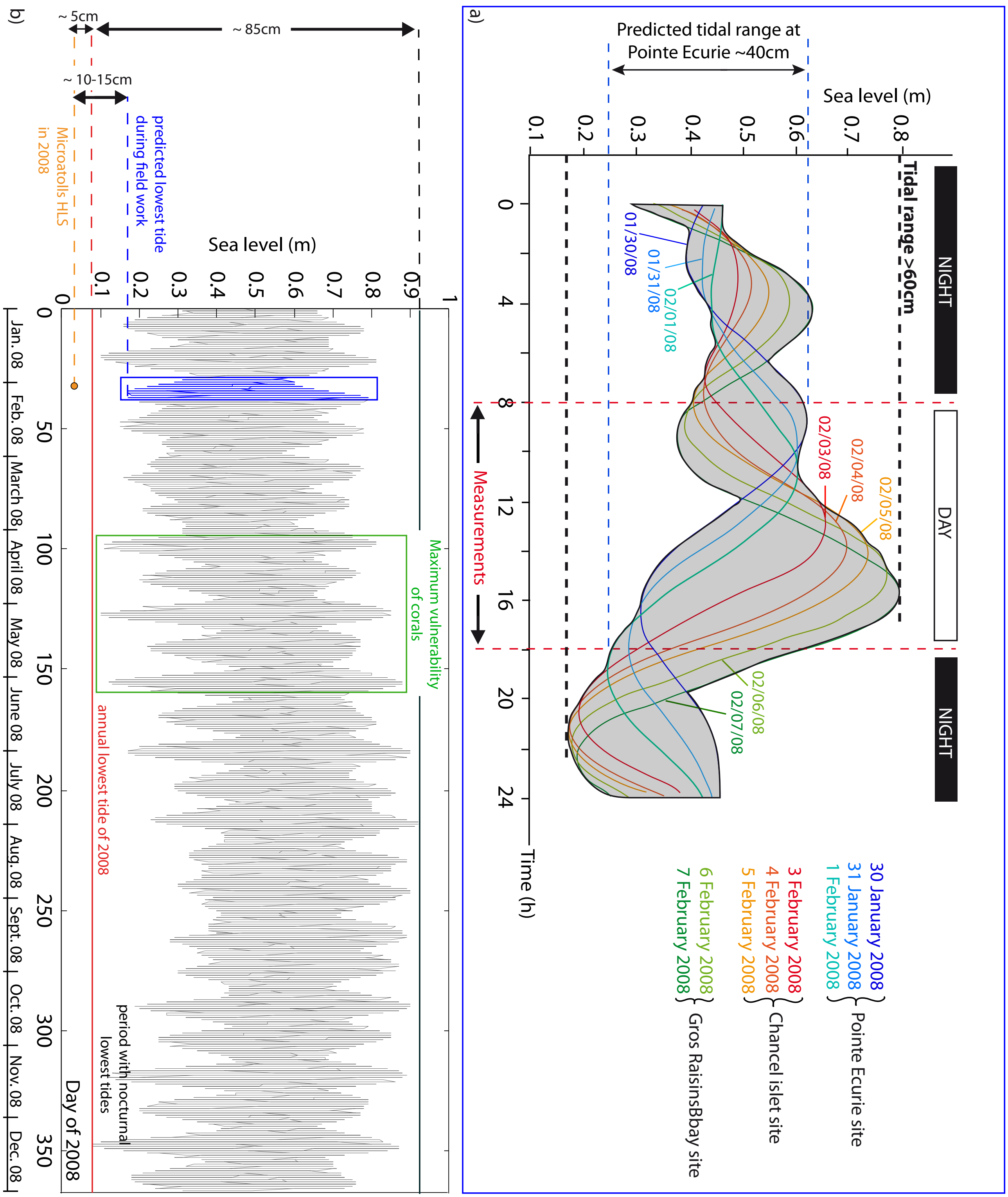

a)
Predicted tidal range at Pointe Ecurie ~40cm
Sea level (m)
Tidal range >60cm
NIGHT
DAY
NIGHT
Measurements
Time (h)
01/30/08
01/31/08
02/01/08
02/03/08
02/04/08
02/05/08
02/06/08
02/07/08
30 January 2008
31 January 2008
1 February 2008
Pointe Ecurie site
3 February 2008
4 February 2008
5 February 2008
Chancel islet site
6 February 2008
7 February 2008
Gros RaisinsBbay site
b)
~ 85cm
~ 5cm
~ 10-15cm
predicted lowest tide during field work
Microatolls HLS in 2008
Sea level (m)
Maximum vulnerability of corals
annual lowest tide of 2008
period with nocturnal lowest tides
Day of 2008
Jan. 08
Feb. 08
March 08
April 08
May 08
June 08
July 08
Aug. 08
Sept. 08
Oct. 08
Nov. 08
Dec. 08

Figure S9. Tide prediction of the SHOM at the Robert location. a) Hourly SHOM prediction of the water level in the Robert place during the fieldwork. For each day on the field, we use a different color. Dashed red lines: range of measurement times. Dashed black lines: tidal range (part colored in gray) during the fieldwork. Dashed blue lines: tidal range during the first three days we passed at Pointe Ecurie. b) Hourly SHOM predictions of water level in the Robert place in 2008 (drawn with SHOMAR software, http://www.shom.fr/). In blue with a blue rectangle: fieldwork between 01/30/08 and 02/07/08 in a). Green rectangle: period of greatest vulnerability for corals in 2008, when lowest tides occurred during day time.

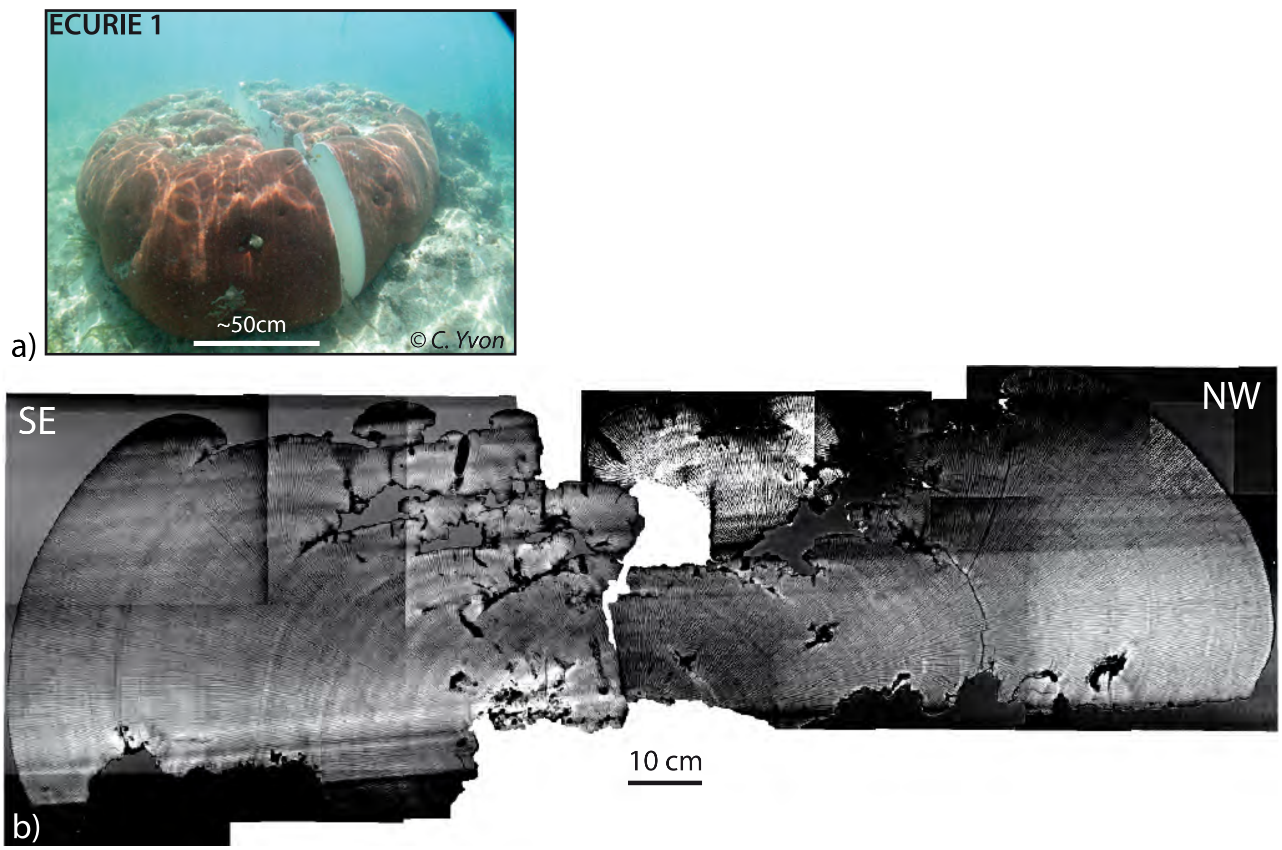


Figure S10. Picture and x-ray of Ecurie 1. a) Ecurie 1 underwater picture. b) Ecurie 1 x-ray.

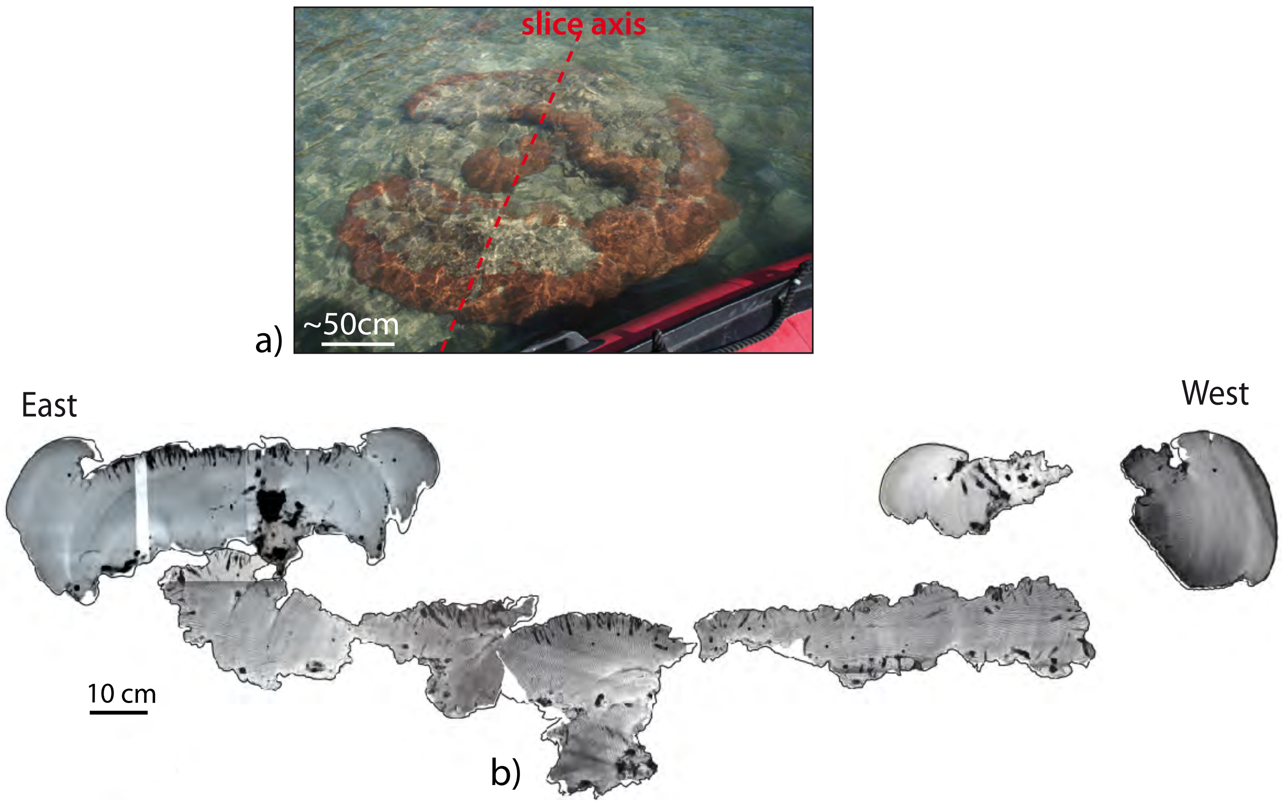


Figure S11. Picture and x-ray of Raisin 1 1. a) Raisin 1 picture with a horseshoe characteristic shape. b) Raisin 1 x-ray.

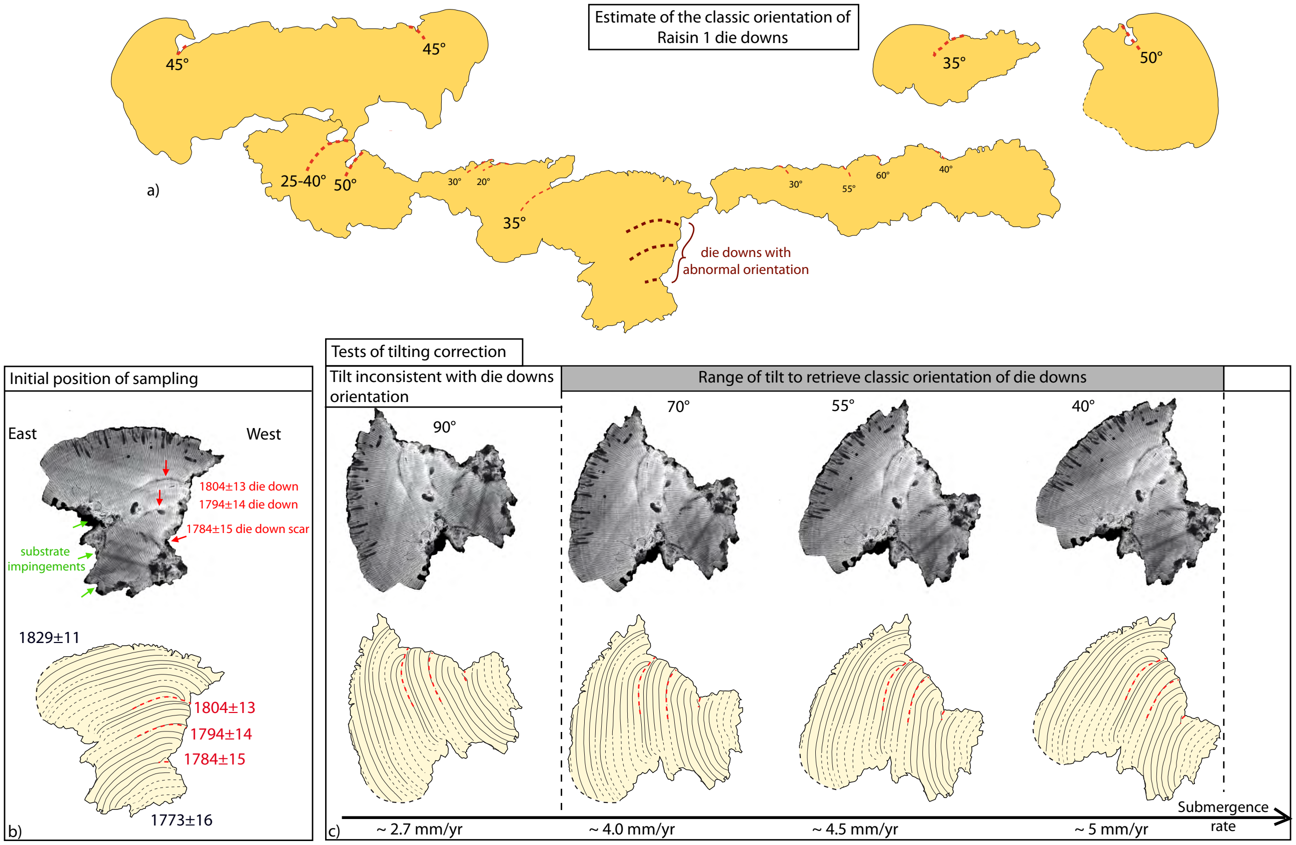


Figure S12. Characterisation of Raisin 1 position before 1829±11. a) Characterization of the orientation of major preserved die downs recorded by Raisin 1 after 1829±11. Minor residual die downs are drawn with smaller dotted lines and their corresponding orientation is written small. The scars of die downs that occurred before 1829±11 are drawn in brown. b) Initial position of the coral (x-ray and corresponding drawing) during sampling, on which we report scars of die downs (red arrows) and of impingements at the base of the coral (green arrows). c) Tests of rotation (x-ray and corresponding drawing) with corresponding net submergence rate [*Zachariasen*, 1998; *Zachariasen et al.*, 2000].

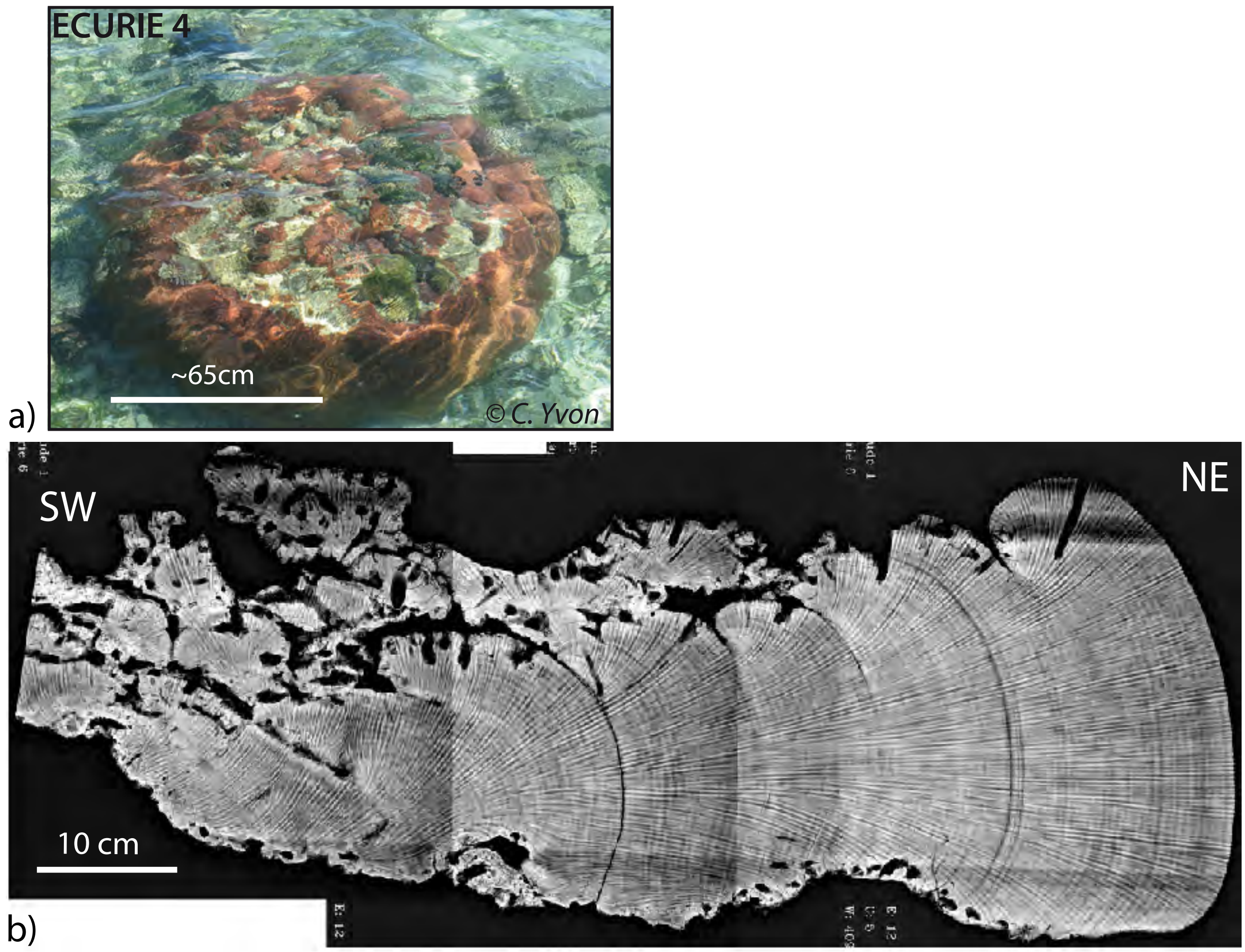


Figure S13. Picture and x-ray of Ecurie 4. a) Ecurie 4 picture. b) Ecurie 4 x-ray.

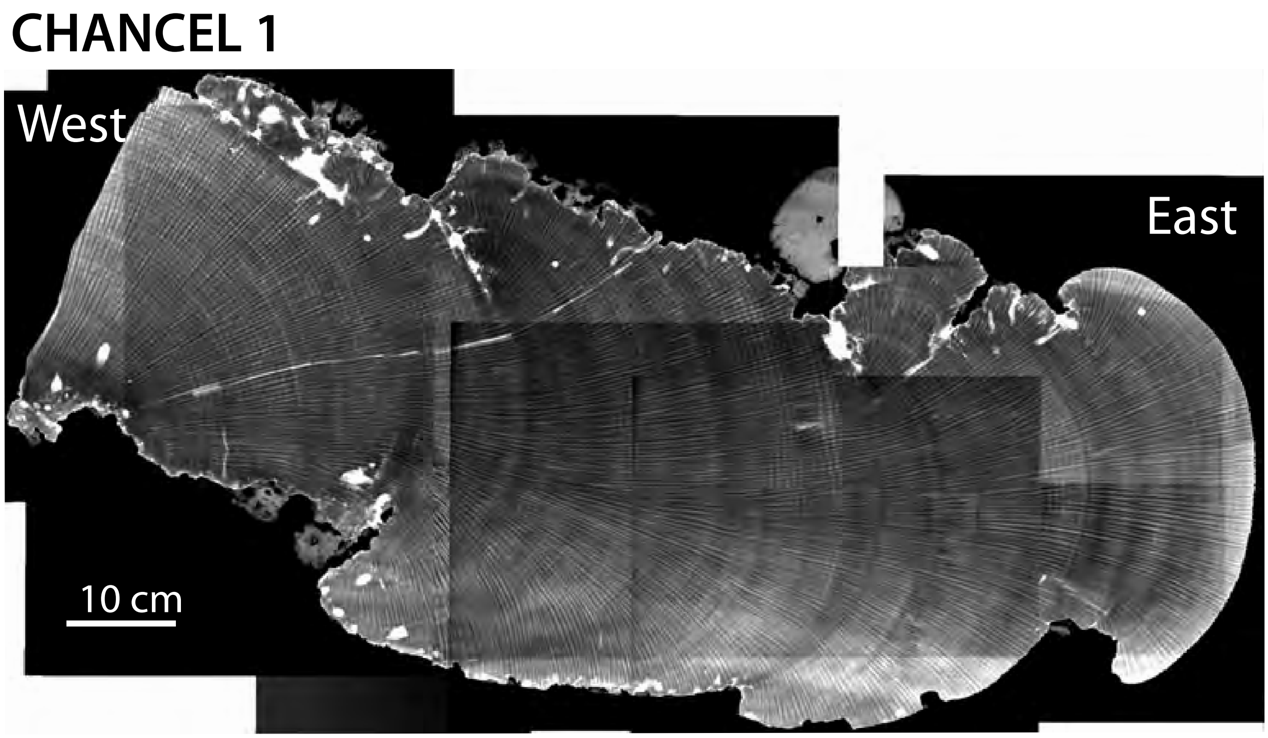


Figure S14. X-ray of Chancel 1.

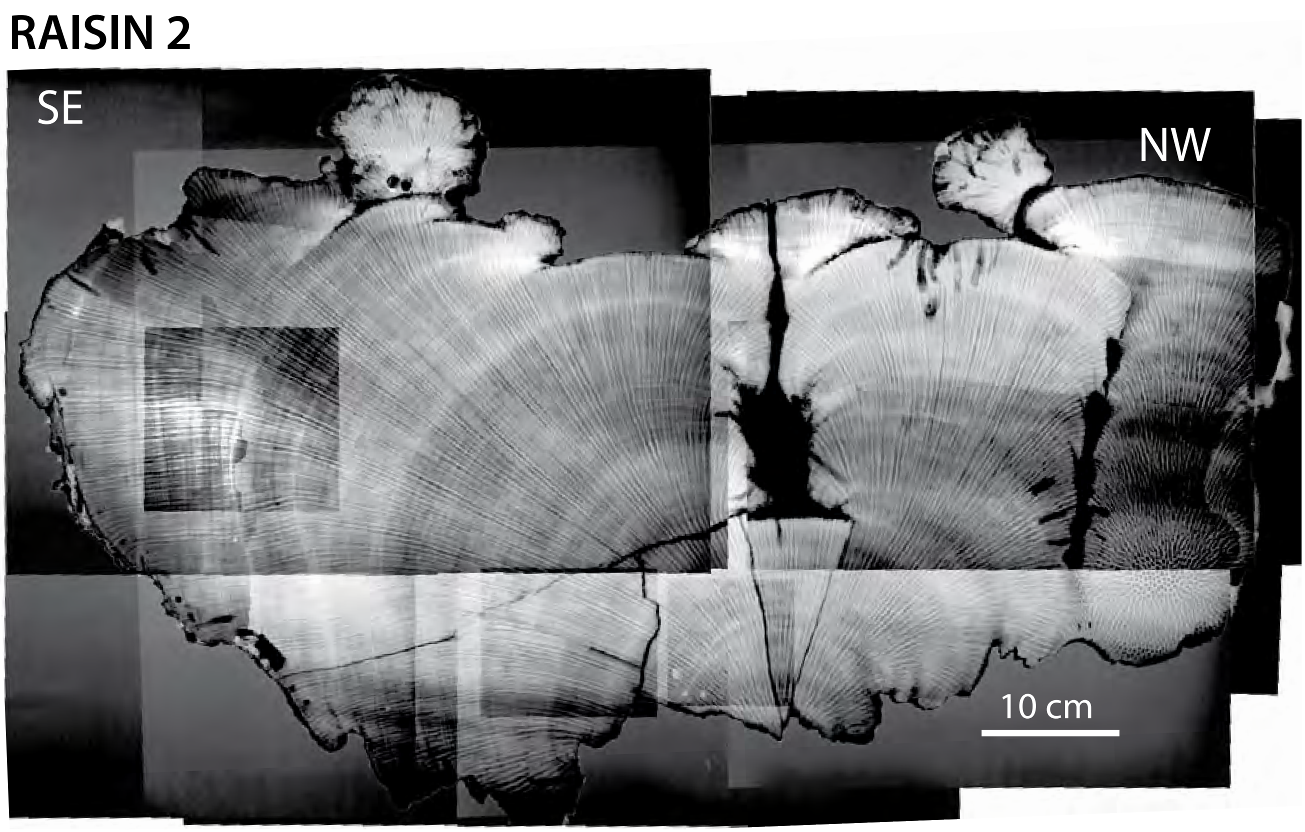


Figure S15. X-ray of Raisin 2.

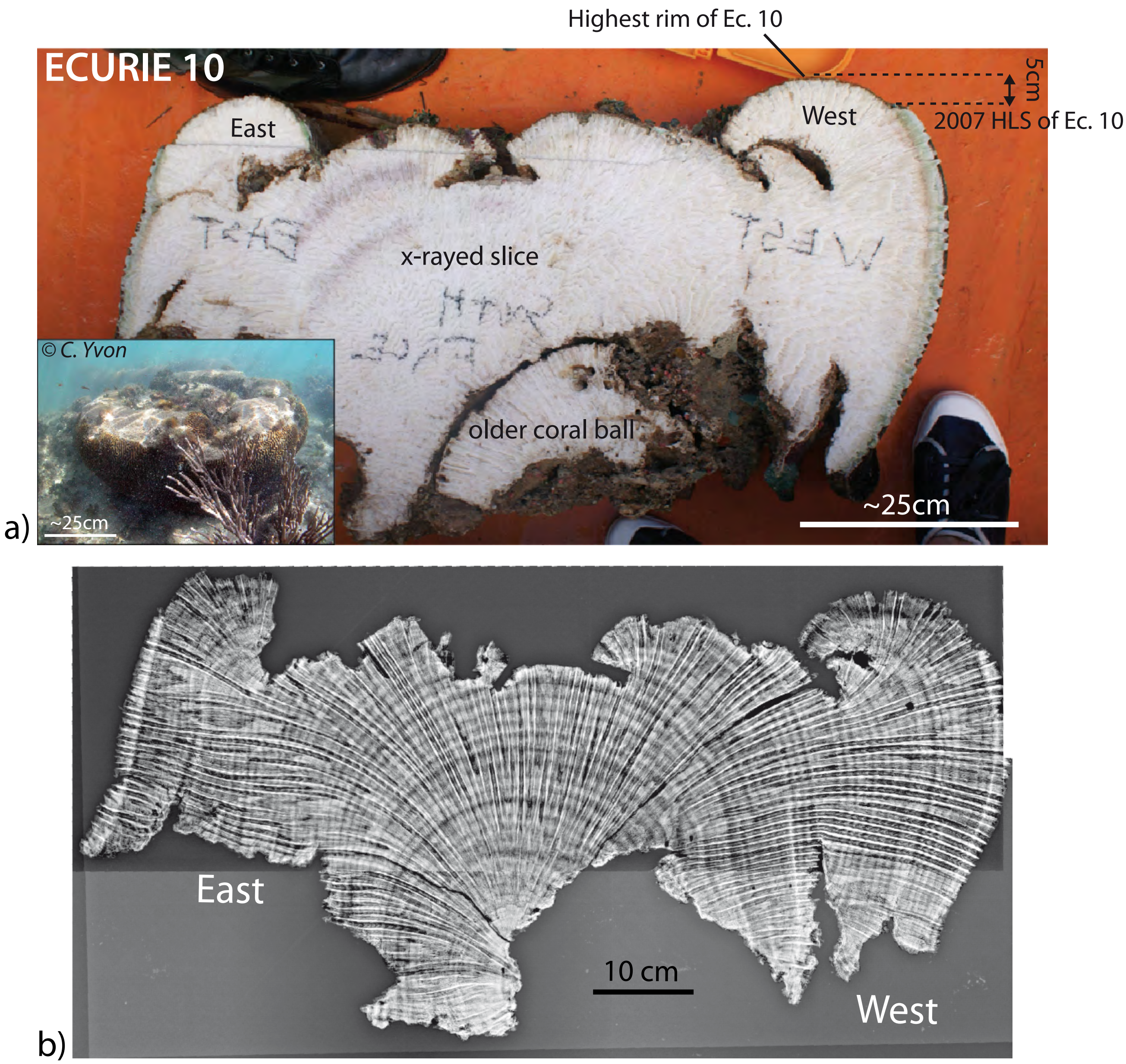


Figure S16. Picture and x-ray of Ecurie 10. a) Picture of the slab of Ecurie 10 we sampled. Inset: Ecurie 10 underwater picture. b) Ecurie 10 x-ray.

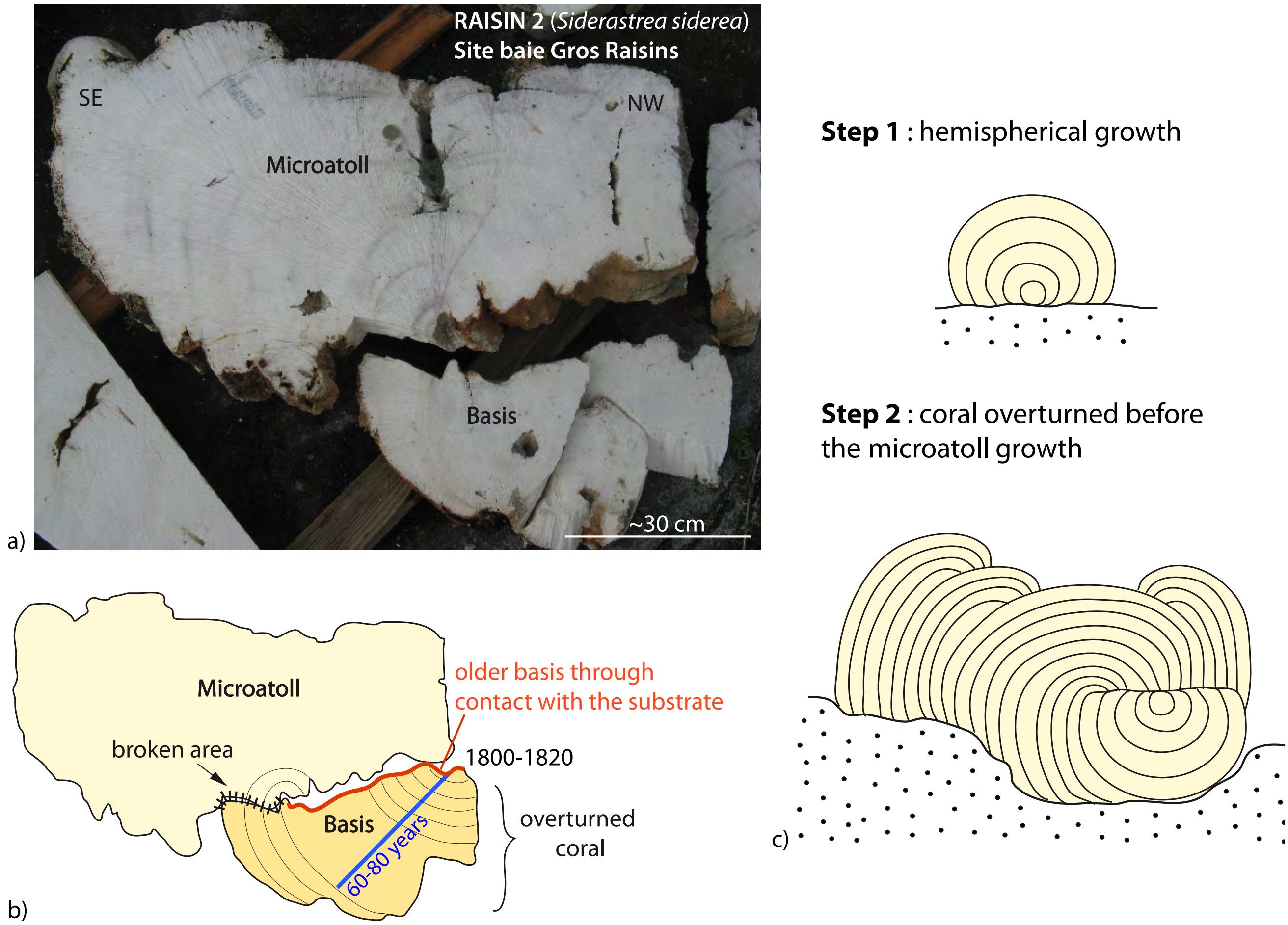


Figure S17. Possible overturning scenario for Raisin 2. a) Photography of Raisin 2 slice. b) Sketch of the Raisin 2 slice, with in dark yellow, the coral base detached from the main slab and not x-rayed. Growth bands have been drawn according to the growth direction observed on the slice. Blue line: record duration estimated in function of the size of the base, the growth rate of the species and counting on the x-rayed part of Raisin 2. c) History of Raisin 2 in two steps. Step 1: Raisin 2 grows and adopts a ball shape. Step 2: the coral is overturned and Raisin 2 continues to grow by recovering the older coral basis, now stuck in the sand.

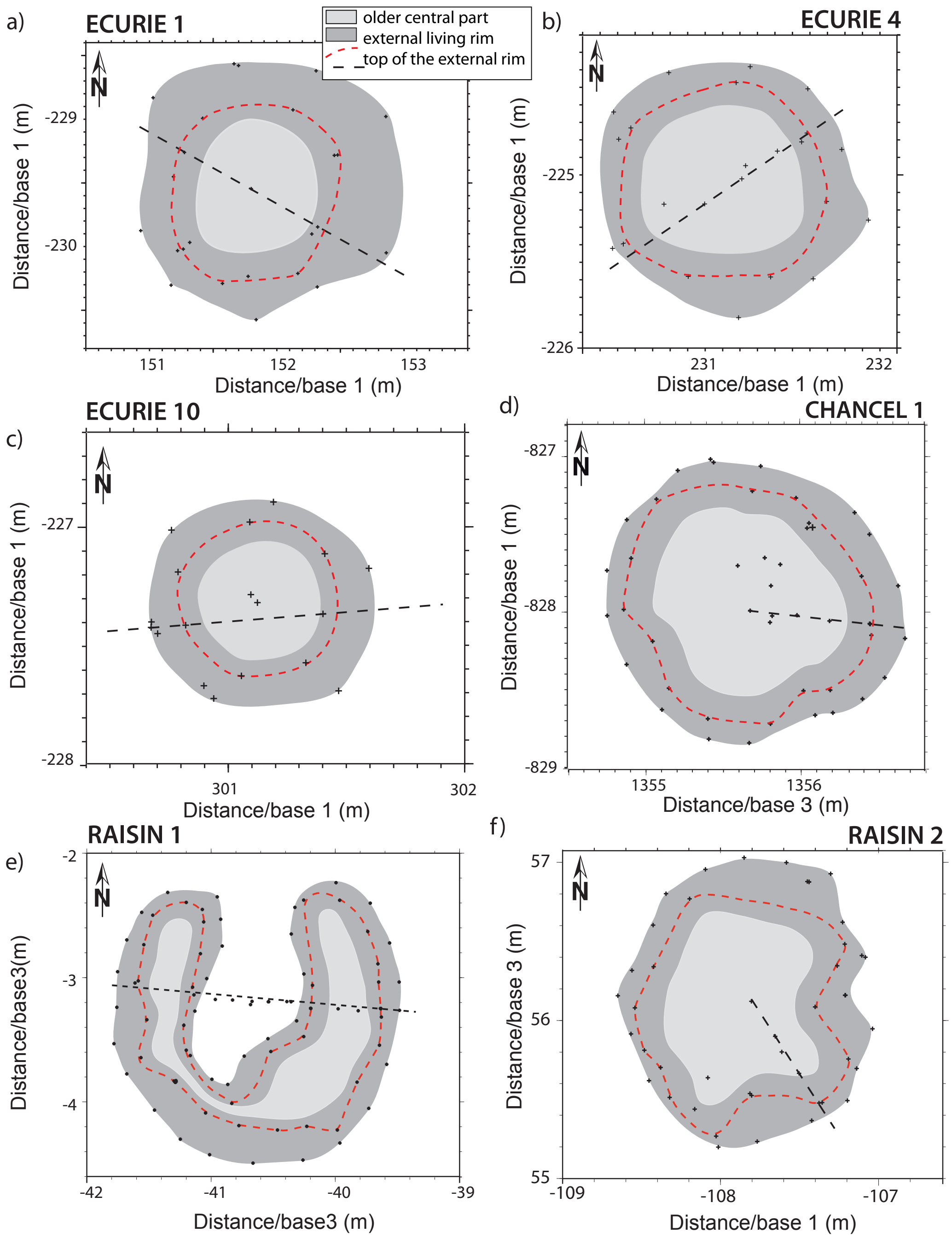


Figure S18. Total station survey of the corals we sampled. a) b) c) d) e) f) Map view of Ecurie 1, Ecurie 4, Ecurie 10, Chancel 1, Raisin 1 and Raisin 2, respectively.

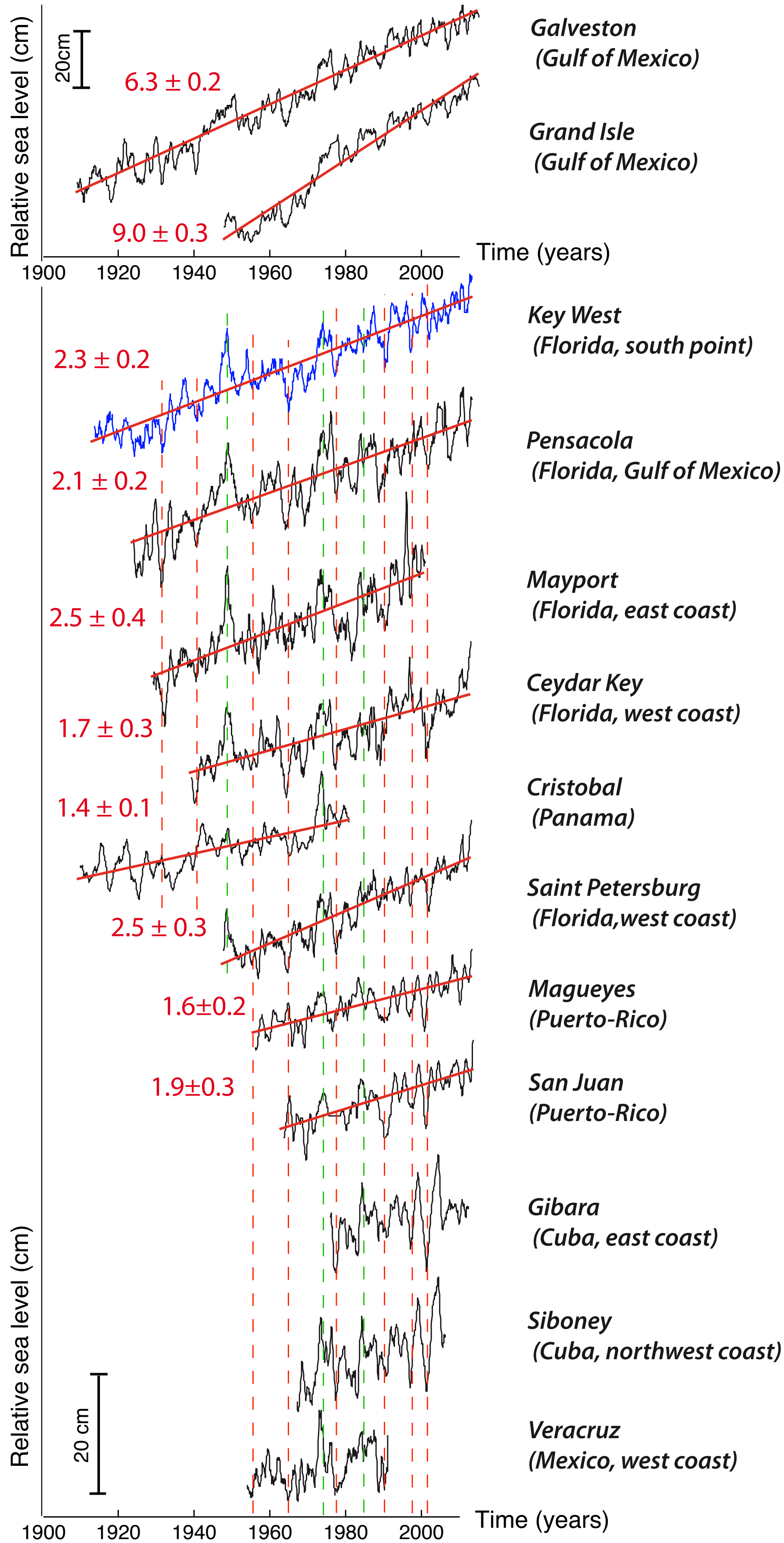

Relative sea level (cm)
20cm
6.3 ± 0.2
9.0 ± 0.3
Galveston
(Gulf of Mexico)
Grand Isle
(Gulf of Mexico)
Time (years)
1900
1920
1940
1960
1980
2000
2.3 ± 0.2
Key West
(Florida, south point)
2.1 ± 0.2
Pensacola
(Florida, Gulf of Mexico)
2.5 ± 0.4
Mayport
(Florida, east coast)
1.7 ± 0.3
Ceydar Key
(Florida, west coast)
1.4 ± 0.1
Cristobal
(Panama)
2.5 ± 0.3
Saint Petersburg
(Florida,west coast)
1.6±0.2
Magueyes
(Puerto-Rico)
1.9±0.3
San Juan
(Puerto-Rico)
Gibara
(Cuba, east coast)
Siboney
(Cuba, northwest coast)
Veracruz
(Mexico, west coast)
Relative sea level (cm)
20 cm
Time (years)
1900
1920
1940
1960
1980
2000

Figure S20. Regional submergence rate, and comparison between tide gauges of the Caribbean, Florida, Panama and Gulf of Mexico (location in Figure 13) from GLOSS (`http://www.psmsl.org/data/obtaining/`) and PSMSL (`http://ilikai.soest.hawaii.edu/woce/wocesta.html`). The two records of Galveston and Grand Isle are plotted separately (owing to their higher submergence rates). The longest annual records of remaining tide gauges are plotted first. Red straight lines: Submergence rate (given in millimeters per year with 2σ uncertainty) calculated by linear regression (LR). Dashed red lines: synchronous negative sea-level anomalies. Dashed green lines: synchronous positive sea-level anomalies. The Key West record is drawn in blue

.

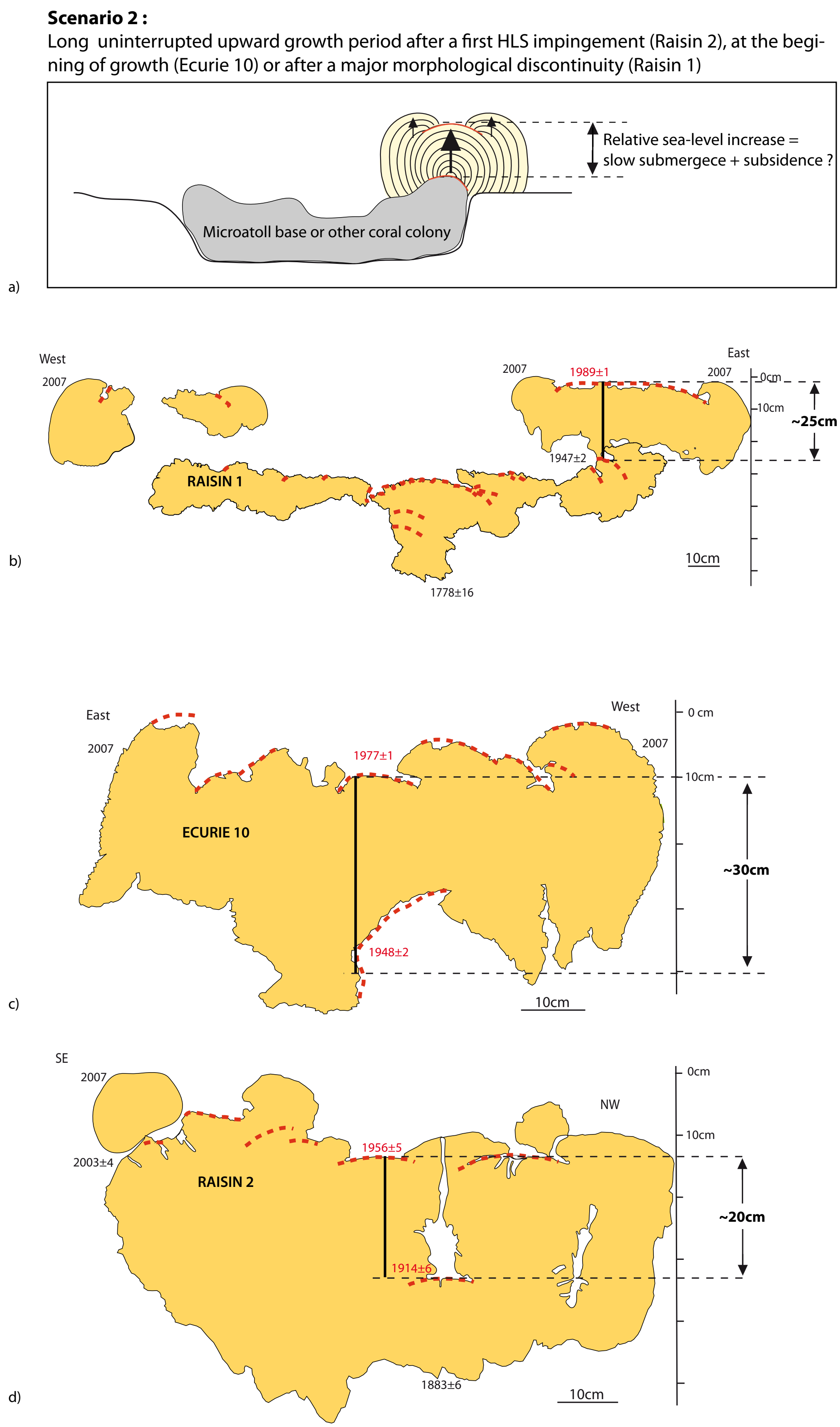
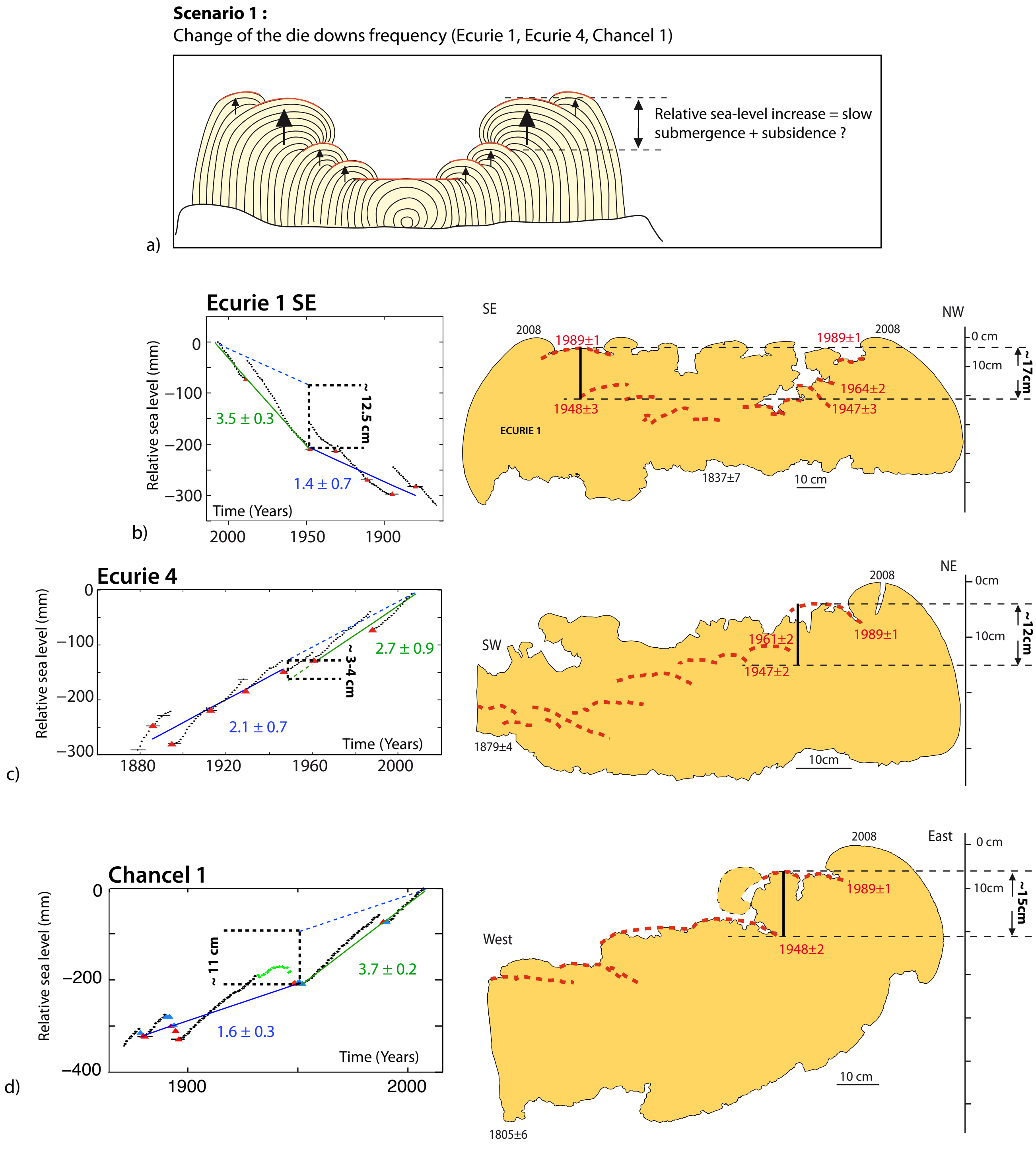

Scenario 2 :
Long uninterrupted upward growth period after a first HLS impingement (Raisin 2), at the begining of growth (Ecurie 10) or after a major morphological discontinuity (Raisin 1)
Relative sea-level increase = slow submergece + subsidence ?
Microatoll base or other coral colony
a)
West
East
2007
1989±1
2007
0cm
10cm
~25cm
1947±2
RAISIN 1
10cm
1778±16
b)
East
West
2007
0 cm
2007
1977±1
10cm
ECURIE 10
~30cm
1948±2
10cm
c)
SE
2007
0cm
NW
10cm
2003±4
1956±5
RAISIN 2
~20cm
1914±6
1883±6
10cm
d)

Figure S20. Submergence calculation around 1950 inferred from microatolls Raisin 1, Ecurie 10 and Raisin 2. a) Schematic drawing of the uninterrupted upward growth period recorded by the three corals. b) c) d) Measure of the relative sea-level increase around 1950 for Raisin 1, Ecurie 10 and Raisin 2, respectively.



Scenario 1 :
Change of the die downs frequency (Ecurie 1, Ecurie 4, Chancel 1)
Relative sea-level increase = slow submergence + subsidence ?
a)
Ecurie 1 SE
Relative sea level (mm)
Time (Years)
3.5 ± 0.3
1.4 ± 0.7
~ 12.5 cm
b)
SE
NW
2008
1989±1
1964±2
1948±3
1947±3
ECURIE 1
1837±7
10 cm
0 cm
10cm
~17cm
Ecurie 4
2.7 ± 0.9
2.1 ± 0.7
~ 3-4 cm
c)
SW
NE
1961±2
1947±2
1879±4
~12cm
Chancel 1
~ 11 cm
3.7 ± 0.2
1.6 ± 0.3
d)
West
East
1948±2
1805±6
~15cm

Figure S21. Submergence calculation around 1950 inferred from microatolls Ecurie 1, Ecurie 4 and Chancel 1. a) Schematic drawing of the record in the stratigraphy of a change in the die down frequency in a submergence setting. b) c) d) Measure of the relative sea-level increase between 1950 and 1990 with HLS curves and slab stratigraphy of Ecurie 1, Ecurie 4 and Chancel 1, respectively. With HLS curves, we calculate submergence rate (in millimeter per year) before 1950 (blue line with number) and after 1950 (green line with number) by linear regression for estimating the relative sea-level increase around 1950 (dashed black lines).